LESSON 7: Plastic Polymers

LESSON'S CONCEPTS

- Properties of different plastics can be identified.
- Some plastics can be reused or recycled.

PURPOSE

Students examine the physical properties of different types of plastic and learn ways to reuse plastic products.

OVERVIEW

In this lesson students will:

- Conduct a series of tests to determine the properties of different types of plastics.
- Test plastics for decomposition by burying them for several weeks.
- Develop a rubric for assessing the value of their invention of new uses for a plastic item.
- Invent new uses for a plastic item.
- Audit the plastic waste generated in their homes.
- Identify new practices which would generate less plastic waste.

CORRELATIONS TO CALIFORNIA'S CONTENT STANDARDS AND FRAMEWORKS AND TO *BENCHMARKS FOR SCIENCE LITERACY*

- Students compare the properties of plastics and classify them according to resin type.
  - "Many forms of matter are identifiable by their color, texture, or shape; by their hardness or flexibility . . .." (*Science Framework*, page 41)
  - "Through science and technology, a wide variety of materials that do not appear in nature at all have become available . . .." (*Benchmarks for Science Literacy*, page 188)
  - Students "classify objects . . . based on appropriate criteria." (*Science Content Standards, Grades K–12*; Grade 5; Investigation and Experimentation, Standard 6a)
  - Students "analyze problems by identifying relationships, distinguishing relevant from irrelevant information, sequencing and prioritizing information, and observing patterns." *(Mathematics Content Standards for California Public Schools, Kindergarten Through Grade Twelve*, page 19)
- Students invent new uses for a plastic item.
  - "Students create original artworks based on personal experiences or responses." (*Visual and Performing Arts Framework,* Visual Arts Education: Creative Expression Component, Goal 4, page 101)

SCIENTIFIC THINKING PROCESSES

observing, communicating, comparing, classifying, relating

TIME

30 minutes to prepare for the lesson; 90 minutes to implement each of the three parts in the lesson, plus time throughout the week for students to work on their inventions; and 45–60 minutes after the decomposition test is completed (about three months later)

VOCABULARY

plastic, polymer

PREPARATION

___ **1.** Read the "Background Information for the Teacher" at the end of this lesson.

___ **2.** About a week before you begin this lesson, ask students to bring to class a variety of plastic containers. Emphasize that these plastic containers should be rinsed out and should not have contained any hazardous substances. From each type of plastic, plastic container codes 1, 2, 3, and 6 (the code is usually embossed on the bottom of the container), cut a piece approximately two inches square and label with the plastic container code number, using a permanent marker. Make a set of these for each group of three or four students.

Note: The terms "plastic container code", "resin code", "plastic's resin number", "code number", and "plastic code number" are used interchangeably to describe the number embossed on the bottom of plastic containers.

___ **3.** Find out what plastics, if any, are recycled in your community.

___ **4.** Make a copy of "Test Your Plastic Polymers" (page 391) and "Plastics Coding System" (page 393) for each group of three or four students; and "Plastics at Home" (page 396) and "Plan for Inventing a New Use for a Plastic Object" (page 395) for each student.

MATERIALS

For "Pre-Activity Questions"

___ Plastic sandwich bag
___ Sharpened pencil
___ Sink or bucket

For "Part I, Analyzing the Properties of Plastics"

___ A piece of 2-inch-square plastic from each of the following plastic containers, for each group of students:
___ Polyethylene terephthalate (PETE) (plastic container code #1 from 2-liter soft drink bottles)
___ High density polyethylene (HDPE) (plastic container code #2 from gallon jugs for milk or water)
___ Polyvinyl chloride (PVC) (plastic container code #3 from glass cleaner bottles)
___ Polystyrene (PS) (plastic container code #6 from foamed plastic plates, coffee cups, egg containers)
___ Several plastic dish pans or buckets for the float test
___ A copy of "Test Your Plastic Polymers" and "Plastics Coding System" for each group of three or four students

For "Part II, Inventing New Use for a Plastic Item"

___ A plastic item for each student
___ A copy of "Plan for Inventing a New Use for a Plastic Object" for each student
___ Art supplies

For "Part III, Testing to Determine Whether Plastics Biodegrade or Break Down"

___ A piece of 2-inch-square plastic from each plastic resin used in this lesson
___ A piece of 2-inch-square paper from four different types of paper (e.g., cardboard, copy paper, construction paper, and paper towel)
___ Two nylon stockings or mesh bags (e.g., onion bags)
___ Outdoor planter, garden area, or other area in which the bags can be buried; or a large (12- to 16-inch) flower pot

For "Application"

___ A copy of "Plastics at Home" for each student

PRE-ACTIVITY QUESTIONS

A. Write on the chalkboard or on a piece of butcher paper: "What We Know About Plastics." Ask students to describe what they know about plastics, as you record their comments on the chalkboard or butcher paper. For example, can they tell you what are plastics and from what they are made?

What We Know About Plastics

- *Made from chemicals*
- *Good for storage*
- *Can seal liquids*
- *Can be air tight—nonporous (air can't go through)*
- *Strong*
- *Tough*
- *Durable*
- *Melts*
- *There are different kinds*
- *Birds get stuck in six-pack holders*

Submitted by Janet Cohen's sixth-grade class, Gold Trail Elementary School, Gold Trail Union School District.

B. Write on the chalkboard or on a piece of butcher paper: "What We Would Like to

(Use school's letterhead.)

Dear Parent or Guardian,

Please read the following information with your child:

We are studying the properties of different plastics. Please send with your child by ______________ ____________ one item from each of the following categories of plastic:

___ Polyethylene terephthalate (PETE) (plastic container code #1: 2-liter soft drink bottle)

___ High density polyethylene (HDPE) (plastic container code #2: gallon jug for milk or water)

___ Polyvinyl chloride (PVC) (plastic container code #3: glass cleaner bottle) (Please rinse the bottle.)

___ Polystyrene (PS) (plastic container code #6: foamed plastic plate, coffee cup, egg container)

Please do not send any plastic containers that have held hazardous substances.

Thank you,

Know About Plastics." Record students' questions. Keep these questions until the end of this lesson. Encourage students to conduct research on any unanswered questions about plastics at the end of this lesson.

C. Conduct the following demonstration:

- Fill a plastic sandwich bag with water.
- Ask for a student volunteer who is brave enough to stand under the bag while you push a sharpened pencil through it.
- Hold the bag over the volunteer's head. Jokingly tell the class that this event has never before been viewed on national television. Slowly rotate the sharp pencil in through one side of the plastic bag and out the other side. No water should leak out. (Do not push the pencil through completely.)
- Ask students to hypothesize why the bag did not leak when the pencil was pushed through.
- Have the volunteer take the bag over to a sink or a bucket and pull the pencil out to demonstrate that a "trick" bag was not used.
- Explain that plastics are formed into long chains, called polymers, by linking together small single chemical units, called monomers. Therefore, polymers are chemical compounds consisting of repeating monomers that form chains. As the pencil is pushed through the bag, it slips between these chains. Unbroken, the chains slide around the shape of the pencil, sealing in the water. A dull pencil, however, breaks the chains and causes the bag to leak. When the pencil is removed, the polymers may move somewhat towards their original shape, but not enough to close the large pencil hole.

PROCEDURE

Part I, Analyzing the Properties of Plastics

A. Provide a set of equal-sized pieces from four different types of plastics (soda bottle, milk jug, glass cleaner bottle, polystyrene cup or plate) and a copy of the chart, "Test Your Plastic Polymers," for each group. Ask students to discuss in their groups what type of results they expect to observe from their investigations.

B. Ask students to look at the number found inside a triangle on the bottom of each container. Tell them to record on their charts the plastic container code number on the four types of plastics.

C. Have students investigate properties of plastics by conducting the following four tests on each of the four pieces of plastic:

Picture intentionally deleted.

A student in Nona Reimer's fifth-grade class at John Malcom Elementary School determines a container's type of plastic resin.

1. Texture test
2. Flex tests (to determine pliability)
3. Float test
4. Scratch test (Students can use their fingernails or a paper clip.)

D. Distribute a copy of "Plastics Coding System" to each group. Ask students to complete their charts, "Test Your Plastic Polymers."

E. Encourage groups to share their results. Discuss the properties of the different types of plastics (e.g., some are stiff, others are light and flexible). Discuss why a particular type of plastic might be chosen for each type of package.

The following are what students should discover from their tests:

1. Polyethylene terephthalate (PETE), plastic container code #1:
   a. Smooth
   b. Highly resilient
   c. Sinks in water (specific gravity: 1.40)
   d. Hard to scratch

2. High density polyethylene (HDPE), plastic container code #2:
   a. Textured
   b. Semirigid to flexible; does not crack when bent
   c. Floats in water (specific gravity: 0.95)
   d. Hard to scratch

3. Polyvinyl chloride (PVC), plastic container code #3:
   a. Smooth
   b. Forms white line when bent
   c. Sinks in water (specific gravity: 1.30)
   d. Scratches easily

4. Polystyrene (PS), plastic container code #6:
   a. It is smooth.
   b. Foamed PS is semirigid, but breaks easily.
   c. Foamed PS floats (specific gravity: less than 1.00). Note: The specific gravity depends on the extent to which the resin is foamed; unfoamed PS sinks (specific gravity: 1.05).
   d. Foamed PS scratches easily.

Note: Specific gravity is the ratio of the density of the plastic to the density of water, which is 1.0. Plastics with higher densities than water will sink. However, some plastics that are supposed to sink floated during field tests.

F. Once students have charted the different properties of the four plastics, ask the following questions:

- Why are there many different kinds of plastic in use? (One answer, based on the chemistry of plastics, is that different resins are suited to different uses, depending on their strength, flexibility, and resistance to specific chemicals.)
- Why do plastics have to be separated before they can be recycled? *Each plastic has a different set of properties and is used for specific purposes. If mixed and melted together, the plastics would not have the specific properties needed for the specific uses.*
- Which plastics are recycled in our community? (You might need to tell students or ask them to find out.) Note that plastic containers marked with plastic code numbers 1 and 2 are commonly recycled. Other plastics, usually not used for beverage containers, can possibly be recycled but are often not accepted at most recycling centers. Many types of plastic are not being recycled because there are not enough companies that

Picture intentionally deleted.

Students from Janet Cohen's sixth-grade class at Gold Trail Elementary School conduct a float test on different pieces of plastic.

make products from recycled plastics due in part to the difficulty of separating different types of plastic resin.

G. Explain to students that the recycling process for plastic containers includes: (1) sorting the containers by their resin types; (2) cutting the plastic into tiny pieces, called pellets; (3) melting the pellets; and (4) reshaping into new plastic objects.

Part II, Inventing New Use for a Plastic Item

A. Tell students that they will be developing a new use for a plastic item that was going to be thrown into a garbage can. They will need to make some adjustment to the way the plastic item looks at this time. Show the different plastic items brought by students. Select one or two items, brainstorm ideas with students for new uses for this plastic item, and list the ideas on the chalkboard.

B. Develop a rubric to help students identify how they will be judged on this project. One way to do this is to complete part "C" of the rubric with minimum basic requirements. Let the students formulate, with your assistance, the "A," "B," and "D" parts of the rubric. Proofread the rubric together and carefully go over it to make certain every student understands every part of the criteria that make up the rubric.[1] An example of a rubric is provided at the end of this lesson (page 394).

C. Allow students to select a plastic item from those brought in by students. One way to do this is to put all the plastic items in a box and have students select one with their eyes closed.

- Provide a copy of "Plan for Inventing a New Use for a Plastic Object" for each student. Students can use an idea from the list brainstormed by the class or come up with another idea. Have students complete their plans about what they are going to make, how they will make it, and what materials they will need to make it.
- Review and approve each plan.
- Provide additional materials for students to facilitate their inventions.

D. Agree on a time when the projects (and reports, if included in the rubric) are due. Provide time throughout the week for students to complete their projects.

Note: It is recommended that you provide instructions for a related project for students to do if they finish early.

E. Allow enough time (usually a day or two) for students to present their project and for the class to grade each project, using the established rubric as a guideline.

Picture intentionally deleted.

A group of students from Janet Cohen's sixth-grade class at Gold Trail Elementary School design a project using 2-liter plastic bottles.

[1]Jacqueline Faber and Melissa C. Williams, *PBL: Beginning Steps—It's a Process!* Paper presented at the Fifth Annual Conference on Project–Based Learning, March 10, 1997.

Picture intentionally deleted.

Two students from Janet Cohen's sixth-grade class at Gold Trail Elementary School present the project they made from a plastic box.

Part III, Testing to Determine Whether Plastics Biodegrade or Break Down

A. Place pieces from the four types of plastics in a nylon stocking or mesh bag. To have something to compare, also place two-inch pieces of four different types of paper (e.g., cardboard, copy paper, construction paper, paper towel) in another nylon stocking or mesh bag. Bury both stockings or mesh bags in an outdoor planter, garden area, or other area. Do not use sterilized potting soil, because it contains no microorganisms to decompose material. Keep the soil moist. Check the item buried in three months.

Note: The items can also be buried in a large flower pot and kept indoors.

Note: Samples from four types of plastic can also be nailed on pieces of wood and placed in the sunlight to see whether they break down in the presence of sunlight.

B. Discuss the concept of "biodegradable" plastic bags. Mention that most "biodegradable" plastics are made by splicing molecules of cellulose in between the regular polymer chains. Certain organisms possess the enzymes necessary to break down the cellulose molecules. When conditions are right, they can digest the cellulose, splitting up the synthetic polymer chains in the process. As a result, the plastic bag breaks into little bits of nonbiodegradable plastic. Ask students what the problems might be with little pieces of plastic.

Three Months Later

C. After three months have students unbury and check their plastics and paper products. Discuss with students:

- What did we find out?
- Why do plastics not biodegrade? One hypothesis is that since plastic polymers are synthetic and have existed on Earth for such a short time, few, if any, organisms have developed enzymes that can break down their long polymer chains. Ask students how a species might evolve or develop such a capability. How might this capability benefit the species that evolves it?
- Should we bury these items for an additional amount of time?

APPLICATION

A. Ask students to look at the chart developed in "Pre-Activity Questions." What can we add about what we know about plastics? List students' responses on the chart. Are there any corrections needed to make the statements more accurate?

B. Discuss ways that students can reuse the plastic containers. Generate a list and post it in the classroom. Students can illustrate each use and add new uses. Encourage students to bring plastics from home and think of ways to reuse them for classroom use.

C. Ask students to write in their journals what they can do to generate less plastic waste.

D. Ask students which of the plastic container code numbers they might select when deciding on what product to buy in a plastic container. *Numbers 1 (PETE) or 2 (HDPE.)* Ask them to explain their answers. *These plastics are the ones most often recycled.* Share with students that although we may place our plastic containers in a recycling bin, it does not mean that they will be recycled. Several types of plastic containers are not recycled, because products made from recycled materials are not always profitable.

Homework Assignment: Provide a copy of "Plastics at Home" for each student. Ask students to conduct an audit of kitchen cupboards in their homes and to complete the chart, "Plastics at Home." They should identify eight plastic containers, such as a milk jug, polystyrene plate, and soda bottle, and record the product and brand (including the size of product); plastic container code number; whether the plastic is recyclable in their community; and the way it will probably be disposed (landfill/recycling center). Then the students should list ways each plastic product can be reused. Finally, they will list some reusable and recyclable substitutes for three of the plastic products that were going to go to the landfill.

Note: Some plastic products, such as plastic utensils, or plastic bags might not have a code number.

E. Have students share the results of their homework assignment. Review what plastics are recyclable in your community and what plastics will probably be placed in landfills.

Extensions

A. Students can conduct additional tests on plastic.

- To differentiate plastic container code #2 (HDPE) from #4 (LDPE) and #5 (PP), use isopropyl alcohol.

  Plastic #2 will sink while plastics #4 and #5 will float in isopropyl alcohol.
- To differentiate between plastic container code #4 and code #5, use Mazola brand corn oil (which has the correct density to separate #4 and #5) to test for buoyancy. Plastic #4 sinks in the oil and plastic #5 floats on the oil.

Safety Note: When using isopropyl alcohol, students must wear gloves and protective eye gear.

B. Ask students to think of some everyday items made of plastic and the qualities that they ought to possess. Sample items might include car bumpers, cutting boards, ice cube trays, and laptop computer cases. Have students guess what kinds of plastic these items might be made from and then verify—through testing, reading manufacturer's specifications, or locating information in other sources—to learn what type of plastic they are actually made from. What happens to these items once they are no longer wanted? Ask students to report their findings.

C. Look at the chart developed in "Pre-Activity Questions." Ask students to select any topic to research listed under "What We Would Like to Know About Plastics." Have students share their findings with the class.

D. To test whether degradable plastic really degrades, do the following:

- Obtain examples of the following plastics: (1) photodegradable; (2) cornstarch, biodegradable; (3) nondegradable from a water or milk jug; and (4) nondegradable plastic wrap.
- Cut four equal-sized pieces from each type of plastic.
- Nail a sample of each type of plastic on four separate blocks of wood. Label each block of wood, "A," "B," "C," and "D."
- Place "A" in an area that receives a lot of sunlight, but where it will not be disturbed.
- Bury "B" in the ground or in a planter box.
- Place "C" in water.
- Allow the students to decide where to place block "D."
- Have students record any changes every week for the first month and every month after that for several months.

Resources

Videos

Kids Talkin' Trash. San Leandro, Calif.: Alameda County Waste Management Authority, 1995 (14 minutes). Distributed by the California Integrated Waste Management Board

Students learn how to make less garbage and protect the environment by practicing the four R's: reduce, reuse, recycle, and rot.

Reuse. Protecting Our Environment series. Chatsworth, Calif.: Pied Piper/Aims Media, 1992 (13 minutes).

Shows how household items can be reused. Includes information how to reuse yard trimmings, containers, and appliances. Also available in Spanish. For grades four through six.

Website

For information on plastics, visit the website for the Plastics Marketing Guide at: www.ciwmb.ca.gov/Plastic/Markets/Default.htm.

Book

The Plastic Waste Primer: A Handbook for Citizens. Prepared by the League of Women Voters Education Fund. New York: Lyons & Burford, Publishers, 1993.

Activity Guide

Plastic Eliminators: Protecting California Shorelines (Learning Activities for Youth Groups, Age 10–15). Santa Barbara: California Aquatic Science Education Consortium, nd.

Contains activities that describe for students how to deal with the problems of plastic debris that affect marine life, how to recycle plastics, and how to participate in the Adopt-a-Beach program sponsored by the California Coastal Commission.

To help consumers identify more easily the different types of plastic, the industry has developed a numbered coding system. These

Student's Page

TEST YOUR PLASTIC POLYMERS

Plastic item	The plastic container code (e.g., 1, 2, 3, 6)	Type of plastic (e.g., PETE, HDPE, PVC, PS)	Float test: sink or float	Texture test: smooth or textured	Flex test (Does it bend?): yes or no	Scratch test: easy or hard
Soda bottle						
Milk, water, or juice jug						
Glass cleaner bottle						
Foamed plastic cup, egg carton, or plate						

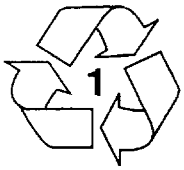
Teacher's Page

ANSWERS TO "TEST YOUR PLASTIC POLYMERS"

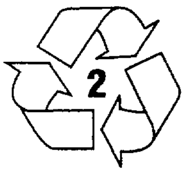
Plastic item	The plastic's container code (e.g., 1, 2, 3, 6)	Type of plastic (e.g., PETE, HDPE, PVC, PS)	Float test: sink or float	Texture test: smooth or textured	Flex test (Does it bend?): yes or no	Scratch test: easy or hard
Soda bottle	1	PETE	Sinks	Smooth	Yes	Hard
Milk, water, or juice jug	2	HDPE	Floats	Textured	Yes	Hard
Glass cleaner bottle	3	PVC	Sinks	Smooth	Yes, forms white line when bent	Easy
Foamed plastic cup, egg carton, or plate	6	PS (polystyrene that is in the form of foam)	Floats	Smooth	No (breaks easily)	Easy

PLASTICS CODING SYSTEM

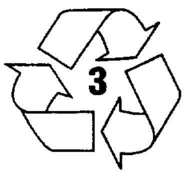
code numbers are embossed on the bottom of containers and other plastic items or printed on plastic bags. Number 1 and the unpigmented 2 types of plastics are most commonly recycled.



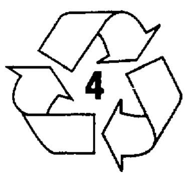
PETE (polyethylene terephthalate): Plastic is soft, generally clear. This plastic is used for food and beverage containers, such as soda bottles, cooking oil bottles, and peanut butter jars.



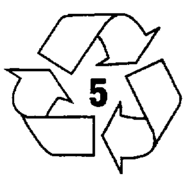
HDPE (high density polyethylene): Plastic is translucent or white or colored. This plastic is used for milk, water, and juice bottles, bleach and detergent bottles, margarine tubs, and some grocery bags.



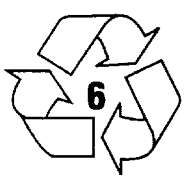
PVC VINYL (polyvinyl chloride): Color of plastic varies. This plastic is used in glass cleaner bottles, some cooking oil containers, and some detergent powders. (PVC has properties of good chemical resistance, which is important for holding household detergents and other harsh materials.)



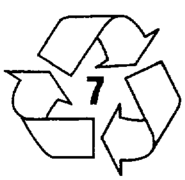
LDPE (low-density polyethylene): Color varies. This plastic is used in food packaging, shrink wrap, carry-out bags, and heavy-duty bags.



PP (polypropylene): Color of plastic varies. This plastic is used in butter and margarine tubs, yogurt containers, screw-on caps, and drinking straws.



PS (polystyrene): Plastic may be clear, hard, or in foamed form. This plastic is used in cutlery and plates, foamed plastic coffee cups, egg cartons, meat trays, and yogurt cups.



OTHER: Color varies. Containers made of more than one resin type. This plastic is used in squeezable syrup and condiment bottles and in some microwave food trays.

Adapted from National Polystyrene Recycling Company, *How-to-Recycle Polystyrene*, 25 Tri-State International, Lincolnshire, IL 60069; (707) 945-2139.

RUBRIC FOR ASSESSING WORK ON INVENTION OF A NEW USE FOR A PLASTIC OBJECT

A	B	C	D
1. Complete a plan for inventing a new use for a plastic object.	1. Complete a plan for inventing a new use for a plastic object.	1. Complete a plan for inventing a new use for a plastic object.	1. Missing any of the parts (1–3) in the plan.
2. Make your plastic invention.	2. Make your plastic invention.	2. Make your plastic invention.	2. Worked a little bit on the plastic invention
3. Stay "on task." If working with partners, each member has more than one job.	3. Stay "on task." If working with partners, each member has more than one job.	3. Stay "on task." If working with partners, each member has at least one job.	3. Did not stay on task.
4. Invention is complete, and careful work with details is evident. The invention works.	4. Invention is complete, and careful work with details is evident.	4. Invention is complete.	4. Invention is not complete.
5. Report on the invention is complete and neatly done.	5. Report on the invention is complete and neatly done.	5. Report on the invention is complete.	5. Report on the invention is incomplete.
6. Lots of time, creativity, and work have been put into your invention.	6. Lots of time and work have been put into your invention.	6. Some time and work have been put into your invention.	6. Not much time or work has been put into your invention.

Name: ______________________________ Date: ______________

PLAN FOR INVENTING A NEW USE FOR A PLASTIC OBJECT

1. What I want to do for my invention: ______________________________

____

____

____

____

2. How I will do it: ______________________________

____

____

____

____

3. Materials I will need: ______________________________

____

____

____

____

Name: ______________________________ Date: ______________

PLASTICS AT HOME

Product and size of product in a plastic container	Plastic container code number	Recyclable in your community? Yes/No	Disposal method for this plastic (landfill or recycling center)	How can this plastic be reused?
Example: gallon of milk	2	*Yes*	*Recycling center*	*For a storage container; planter; piggy bank.*
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

List some reusable and recyclable substitutes for three of the plastic containers listed above that are not reusable or recyclable and will probably be sent to a landfill.

1.______________________________

2.______________________________

3.______________________________

BACKGROUND INFORMATION FOR THE TEACHER

The very first plastics were made from cornstarch, but most plastics today are made from natural gas and crude oil. Plastics are made by linking together small single chemical units, called monomers, in repetition to build one large chain-like molecule, called a polymer.

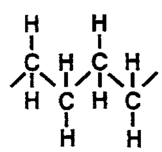
Some polymers are natural substances that come from vegetables and animal sources. They include the horns of animals, tortoise shell from the hawksbill turtle, rosin from the sap of pine trees, and asphalt from decayed plants and animals.[2]

The plastic polymers are made from hydrogen and carbon elements, sometimes in combination with small amounts of oxygen, nitrogen, and other organic and inorganic compounds. For example, polypropylene and polystyrene are polymers that contain only carbon and hydrogen. Nylon also contains nitrogen; and polyvinyl chloride contains chlorine. When rearranged chemically, a solid resin is produced. The resins are used to make hundreds of different plastics, all of which fall into two basic categories: thermoplastics and thermosets.

Repeating unit (monomer):

$-CH_2-CH_2-$

Polyethylene (polymer):



Thermoplastics are formed by combining the same polymer molecules together, like molecules of water. Thermoplastics liquefy at high temperatures and solidify when cool. This property makes it easy to melt the plastic and reform it into new objects. Thermoplastics are used primarily for packaging. Specific types of thermoplastic are polyethylene, polystyrene, polyvinyl chloride, and polypropylene. (For descriptions of these plastics, see "Plastics Coding System" in this lesson.)

Thermosets are formed by combining different polymer molecules. Once linked together in a chemical reaction, they are virtually impossible to separate. They cannot be melted and reformed into new shapes, and this makes them difficult to recycle. Thermosets are widely used in furniture, toys, tableware, computer casings, and other permanent uses requiring a hard plastic. Polyester, epoxies, and melamine are all thermoset plastics.

The various types of rigid plastic containers are coded with numbers to indicate the types of resin from which they were made. These plastic container code numbers are embossed in the bottoms of each container. Plastics with codes 1 and 2 are commonly recycled because they are present in large quantities and have more markets available. At this time only PETE bottles and unpigmented (clear) HDPE bottles are generally recyclable.

According to California Integrated Waste Management Board's estimates, only 3.5 percent of all plastics were diverted from landfills in 1995. Unfortunately, many types of plastic are not being recycled because there are not enough companies that make products from recycled plastic, due in part to the difficulty of separating different types of plastic resin.

Although plastics currently comprise about 6.7 percent by weight of California's solid waste stream, their volume is three times greater than their weight, which means more space is used in the landfill.[3] Plastics are the fastest growing segment of the waste stream.

The popularity of plastics has increased for several reasons. Plastics are durable; lightweight; waterproof; very resistant to chemicals; easily moldable; require less secondary, protective packaging; add to consumer convenience; and are relatively inexpensive to produce. Their chemical properties can be manipulated to achieve just the right combination of properties for any application. The largest markets for plastics in 1994 were packaging and construction industries.[4] However, plastics are made

[2]From *Hands on Plastics: A Scientific Investigation Kit*. Columbus, Ohio: American Plastics Council Incorporated, 1997, p. 2.

[3]Written communication from Edgar Rojas, Integrated Waste Management Specialist, Secondary Materials Section, California Integrated Waste Management Board, October 20, 1998.

from a nonrenewable resource—fossil fuels. Although some plastics are relatively inexpensive to manufacture, the crude oil and natural gas from which they are made come from limited supplies, the increasingly complicated extraction of which often has serious, negative environmental and/or political impacts.

The same characteristics which make plastic an attractive packaging material, also make it a special problem in the waste stream. Though lightweight, plastic is bulky and difficult to compact for shipping or for burial in landfills. Plastic will not biodegrade. Photodegradable plastics may break down into smaller pieces when exposed to enough sunlight but will never really disappear.

The durability of plastics not only makes these synthetic materials very useful but also makes them very difficult for natural systems to recycle. All life forms are dependent on the ability of bacteria, fungi, and other microorganisms to break down natural polymers, such as wood, cotton, and dead organisms, so that the resulting monomers can be used as the building blocks for other life forms. This is where plastic polymers become a problem, because they do not readily decompose under natural conditions. Their chemicals are locked out of the life cycles, effectively removing a natural resource from the environment.

Compounds in "photodegradable" plastics have a chemical bonding that causes these plastics to disintegrate with prolonged exposure to sunlight. These plastics are being used for beverage "six-pack" rings, shopping bags, and in some commercial agricultural applications (e.g., drying trays for raisins). They do break down into smaller pieces of plastic but do not actually decompose.

[4]From *Hands on Plastics: A Scientific Investigation Kit*. Columbus, Ohio: American Plastics Council Incorporated, 1997, p. 3.

Recently the "biodegradable" label has been used for a number of plastics (particularly shopping bags) that use cornstarch or other organic substances as bonding agents in or in combination with crude oil plastics. Like photodegradable plastics, these plastics do break down as their organic matter decomposes, but they degrade into smaller pieces of plastic which do not biodegrade. Biodegradable plastics are generally an impractical solution for disposal of plastic waste. They are typically unable to photodegrade or biodegrade in modern landfills because of the absence of ultraviolet radiation, oxygen, and moisture. Many serious questions also remain about the toxicity of the decomposition by-products associated with biodegradable plastics.

The whole idea of "biodegradable" plastics is not just misleading; it could also draw attention away from more promising answers to the waste problem. These include reducing the amount of plastic we use and developing new methods to recycle the plastic we no longer need.[5]

True biodegradable plastics, plastics that disintegrate into organic substances as the result of natural processes, are largely experimental and have not come into wide use because of their relative high cost.

Note: Additional information about plastics is included on the website listed in the "Resources" section in this lesson; in the "Background Information for the Teacher" in the K–3 Module, Unit 2, Lesson 1; and in "Appendix C–VIII, Plastics."

[5]Evan Hadingham and Janet Hadingham. *Garbage! Where It Comes From, Where It Goes*. New York: Simon and Schuster, Inc., 1990, p. 22.